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Economic considerations on the regulatory framework for offshore wind and offshore meshed grid investments: 3.1 Policy and Regulation

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Economic considerations on the regulatory framework for offshore wind and offshore meshed grid investments

3.1 Policy and Regulation

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Economic considerations on the regulatory framework for offshore wind and offshore meshed grid investments
3.1 Policy and Regulation

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Summary

One of the main technologies for renewable power production, offshore wind electricity (OWE) is an integral component of decarbonising the European power sector. The costs of OWE highly depend on the regulatory frameworks for the provision of wind farms and offshore grids. Regarding generation investment, the distribution of decisional responsibilities and risks between the generators and the regulator is vital for a cost-efficient deployment of offshore wind farms (OWF). Targeted OWE instruments which offer predictable revenues to generators promise significant advantages over decentralised approaches based on the Energy-only market concept. Putting out contracts for building and operating OWFs in locations predetermined by the regulator to competitive tender, appears to be a suitable approach in many cases.

A coherent regulatory framework for meshed grid investments must address network expansion requirements in a cost-efficient manner. In this context we recommend considering four elements: firstly, the harmonisation of the methods for distributing connection costs between transmission system operators (TSOs) and OWE generators; secondly, sharing network development expenses between the involved TSOs in a transparent way; thirdly, similar grid access tariffs for OWE operators; and fourthly, establishing a coherent regulatory regime for the TSOs' cost recovery at the offshore meshed grid level. Future regulatory frameworks for offshore meshed grid will require a strong engagement of policy makers and regulators. The role of European institutions to pave the way to stable and harmonised institutional frameworks is critical.

This report presents the main findings of three comprehensive working papers developed within the scope of Baltic InteGrid (Integrated Baltic Offshore Wind Electricity Grid Development), an interdisciplinary Interreg research project, bringing together experts from Member States present in the Baltic Sea Region to coordinate the implementation of these policy objectives. The goal of the Baltic InteGrid project is to track current regional, national, and European energy developments and propose recommendations to optimise regulatory frameworks.

1. Introduction

Offshore wind power is a very promising technology for the decarbonisation of energy systems. In the past, the levelised costs of electricity (LCOE) from offshore wind farms typically exceeded those of the most efficient onshore wind projects.[1] This was due to the fact that OWE was at a comparatively early stage of development and large experience curve effects were yet to be realised. However, the cost of OWE started to significantly decrease in the last years. Moreover, OWE offers significant advantages over other intermittent RES-E (electricity from renewable energy sources) technologies that are not included in LCOE comparisons. For example, plants have more stable production patterns which translate into increased electricity production values and lower costs of backup capacities. Moreover, offshore locations help avoid land use conflicts as well as negative externalities associated with the use of onshore wind power.[2] Especially with respect to land availability constraints, problems are expected to increase in Europe as countries with a high population density are moving towards ambitious RES-E targets. OWE has thus the potential to play a major role in future European electricity systems.

Large-scale deployment of OWE requires significant investments. Therefore it is highly important to understand the factors that enable or inhibit OWE investments and to identify the best regulatory practices in order to limit the costs of OWE. In principal, this equally applies to both generation investment and grid investment. However, due to the specific characteristics of the two areas, the respective concrete problems and solutions differ significantly. Regarding generation investments, the costs of new OWF can be significantly reduced with an adequate institutional framework in place, which properly allocates decisional responsibilities and risks between generators and the regulator. Moreover, international cooperation on generation projects promises cost savings, but certain obstacles have to be overcome in this context. On the transmission grid's side, OWE development is also associated with large investment costs, as OWF have to be connected to the main grid. In a future with large OWE capacity, more integrated grid architectures could be introduced, replacing the traditional approach of radial connections and thereby coupling interconnection and connection infrastructures, while enabling market interlinkage, cross-border energy exchange and cross-border balancing activities.

Against this background, this report compares different options for the institutional/ regulatory framework for OWE expansion with respect to both generation investments

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[1] Cf. IRENA, "Renewable Power Generation Costs in 2017," International Renewable Energy Agency, Abu Dhabi., 2018. Available at: https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2018/Jan/IRENA_2017_Power_Costs_2018.pdf.

[2] However, other forms of spatial conflicts and negative externalities appear in the case of OWE.

(section 2) and grid investments (section 3). The analysis has a special focus on cooperative approaches, such as joint generation projects and meshed transmission grid solutions. The considerations outlined in this report represent condensed versions of the contents of three research papers created within the framework of the Baltic InteGrid project.[3]

[3] Bibliographic information on the three research papers is provided at the beginning of the following sections. The research papers all extensively incorporate and refer to existing literature on the respective topics. For simplicity, the references are not replicated in this report.

2. Institutional framework for the development of offshore wind power projects (IKEM)

Energy policy plans in Europe intend a large-scale deployment of OWE installations. Meanwhile, the conditions for implementing the expansion plans vary from country to country.[4] The national institutional frameworks for OWE investment differ considerably, with decisional responsibilities and risks heterogeneously distributed between investors and regulators. As the costs of investment and operation highly depend on the market design, identifying the most cost-efficient solutions is thus crucial to enabling OWE deployment. Two main conceptual models of generation investment frameworks are discussed; the **Energy-only Market (EOM)** and the **Capacity Remuneration Mechanism (CRM)**. In practice, when countries have ambitious environmental targets, even apparently EOM-based regimes usually feature **targeted RES-E support instruments** (which, as we will show below, are often **based on the core ideas of the CRM** approach). However, some contributors to the public debate propose phasing out such schemes as soon as possible and recommend to use the EOM as the principal if not sole mechanism for the provision of any kind of generation capacity. This view is highly disputable when basic economic considerations are taken into account. A main goal of the analysis presented in this section is to substantiate the reasons for the advantageousness of targeted OWE instruments. Secondly, we aim at delivering contributions to the debate on OWE instrument design. With these goals in mind, we outline general considerations on the performance of the two basic institutional framework models (section 2.1). Afterwards, we provide an overview of selected OWE remuneration schemes and procurement mechanisms (section 2.2), before concluding with a summary and policy implications (section 2.3).

2.1 Pure EOM approach vs. targeted RES-E instruments

In the **EOM model**, generators sell electricity through direct marketing and receive remuneration payments based on the market price, which fluctuates according to the laws of supply and demand. The EOM model reveals multiple potential problems which are largely related to the existence of transaction costs, impeding the coordination of market actors: Revenue uncertainty for investors leads to structurally high costs of capital.

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[4] The main text of section 2 is based on Albert Hoffrichter, Thorsten Beckers, and Ralf Ott, “Institutional Framework for the Development of Offshore Wind Power Projects – Key Aspects for Instrument Choice and Design from an Institutional Economic Perspective,” Research Paper, 2018.

Uncoordinated investment decisions are likely to result in excesses or shortfalls in target capacities (with shortage occurrences amplified by the market uncertainty). Socially desirable production technology choices are impeded by the fact that investors are, on the one hand, often not able to appropriate all positive welfare effects, while, on the other hand, not being confronted with all social costs. The pricing mechanism of the EOM does not consistently steer investor revenues to risk-adequate levels. The amount of achievable contribution margins is therefore likely to be insufficient for some investors and excessive for others. In general, supplementary regulatory measures (which require centralised planning) could effectively address some of the problems. However, they are often barely compatible with the fundamental ideas of the EOM approach. Considering all these aspects, the EOM approach is unlikely to provide an appropriate framework for OWE investment.

Concerning the **CRM model**, first of all it is important to mention that the public debate on the CRM concept typically refers to comprehensive mechanisms for all plants of the electricity system. By contrast, our considerations relate to the fundamental idea of the CRM approach, which – applied to the provision of OWE – can be summarised as follows: Generators are rewarded for implementing public decisions to build and operate OWE plants; investors are exposed to market risks to a certain degree only (in order to create efficiency incentives). This definition comprises a broad category of instruments, explicitly **including targeted RES-E instruments** which exhibit the described core elements of the CRM concept. The payments to generators may take many forms, such as fixed tariffs or sliding premiums (see section 2.2).

RES-E instruments offer a potential to reduce generation cost significantly compared to the pure EOM model. The extent of realised cost savings largely depends on the regulator's knowledge of the electricity system and instrument design choices. Since the appropriateness of the institutional framework for generation investments highly depends on the characteristics of each generation technology, adapting the design of RES-E instruments to the attributes of the respective technologies promises substantial advantages. In the case of OWE investments especially the following aspects should be considered: OWE projects are very large, both in terms of generation capacities and financial volumes. Planning periods as well as development periods are typically long. Usually regulators are necessarily involved in the choice of plant sites and must take multiple restrictions into account (e.g., maritime spatial planning considerations). Furthermore, OWE projects normally go along with considerable grid investment needs. Therefore the coordination of generation capacity planning and grid extension decisions is exceptionally important; the benefits of **integrated planning** can be expected to be particularly high when meshed offshore grid solutions or other forms of international cooperation are taken into consideration (for an overview of questions in the context of international cooperation on offshore wind (OW) projects, see text box 1). Despite the centralisation of certain general investment decisions, regulatory OWE expansion plans should leave enough room for the incorporation of relevant information and know-how possessed by supply side actors. In this context it is important to establish an effective incentive system which aligns investor decisions with the social objectives.

2.2 Key instrument design questions

RES-E instruments are composed of various design elements. Although each of them potentially plays a significant role for a regime's functioning, we limit the following discussion to an overview of selected remuneration schemes and procurement mechanisms.

2.2.1 Remuneration scheme: FIT, FMP and SMP

As described above, RES-E instruments remunerate generators for implementing the regulator's decisions to install (and operate) RES-E plants. Choosing an appropriate remuneration scheme for OWE investments is important for a large-scale deployment. In light of the high capital intensity of OWE investments (which is primarily related to the lack of fuel costs) the costs of capital are particularly important for the overall cost. Therefore there should be a special focus on the implications for risk allocation when it comes to market design choices.[5] Whenever decisions to build new OWF have been made by the regulator, there are, in principle, good reasons for offering long-term contracts to the actors implementing them. With investors being able to rely on relatively predictable revenues, the costs of capital will be considerably lower than in a situation where amortisation highly depends on future market developments. In order to incentivise an efficient use of resources and the development and application of cost-saving innovations, it is usually reasonable that generators largely bear cost risks; moreover, this approach spares extensive regulatory monitoring.

Remuneration payments can generally be linked to the installed capacity, to electricity volumes provided or to the corresponding production values. In the case of OWE, electricity volumes seem to be a suitable criterion for calculating remuneration payments, as it sets incentives to investors to adapt plant designs to local conditions in order to deliver high contributions to electricity supply. This implies that generators bear production quantity risks. However, since production volumes are comparatively well predictable, the incurred effects on the cost of capital can be expected to be outweighed in most cases by positive efficiency effects of the incentives. In the following we discuss three common RES-E remunerations schemes which refer to electricity volumes: feed-in tariffs (FIT), fixed market premiums (FMP) and sliding market premiums (SMP). In each case, the level of payments can either be determined administratively (i.e., by the regulator) or by means of a competitive process which involves the supply side actors.

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[5] OWE investments are furthermore highly specific, which means that once resources are deployed in the course of planning and implementing projects, they can largely be considered as sunk costs. Abandoning projects usually results in considerable stranded investments.

In the **feed-in tariffs** scheme, generators receive fixed payments per unit of electricity they provide. In order to limit consumer payments, the tariffs should ideally reflect the LCOE, including adequate returns for investors. Even if market prices rise above FIT levels, consumer payments remain stable. If possible curtailments (due to oversupply of electricity at a certain point in time) do not affect revenues, investors bear no market risks. FITs therefore have a high potential for limiting the costs of providing OWE capacity. Only focussing on production volumes, a potential downside of the FIT approach is that it provides incentives to maximise the mere quantity of the output. Sometimes, the OWF layout which promises the highest production volumes might not lead to the highest aggregate production values (for instance due to particularly intermittent production patterns). If this should be considered a relevant problem, it should be assessed whether investor decisions can be improved by modifying the incentive structure. One way of doing this is to confront investors with market risks, which is part of the feed-in premium instrument.

With **feed-in premiums** in place, generators are typically responsible for selling electricity in exchange of market revenues. Additionally, they receive a premium on the production volume that can be **fixed or sliding**.

When generators receive **fixed market premiums**, they bear full market risk. Compared to an EOM system (in which generators only receive market earnings), the risk's impact on the cost of capital is reduced due to higher overall revenues. Nevertheless, costs of capital in a FMP scheme will typically be significantly higher than in a FIT system.[6] Moreover, there is usually no revenue limitation in situations of high market prices, which can lead to excessive consumer payments. A reduction of payments in such situations would be conceivable, but withholding the investors' upside risk when they still bear the downside risk seems to contradict the idea of the FMP. Therefore the overall consumer payments in an FMP scheme are likely to exceed FIT levels. Regarding the OWF layout and achievable production values, there are no clear indications that bearing full market risk leads to substantially improved investor decisions; high uncertainty regarding future market price structures makes significant impacts on investment decisions rather unlikely.[7] Hence, in

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[6] Very high market premiums theoretically render market risks irrelevant for the costs of capital, but at the same time they substantially decrease efficiency incentives, while leading to exceptionally high consumer payments.

[7] Market price risks should only be allocated to generators, if the following conditions are met: i) Certain OWF design concepts increase both the production value and cost; ii) relevant value and cost differences are not known to the regulator; iii) market prices and production values are closely correlated; iv) future market price developments are sufficiently predictable for investors over the relevant period of operation to opt for technical concepts which promise higher revenues

light of the high costs of capital, it is hard to image that FMP schemes may lead to an efficient large-scale OWE deployment.[8]

Sliding market premiums can be regarded as a hybrid of FMPs and FITs. Similar to the FMP approach, generators receive premiums on top of their market earnings. However, as suggested by the name, SMP levels vary over time, representing the difference between the FIT level − which serves as a benchmark − and the average market price achieved by plants of the respective generation technology (in our case OWE) in a certain period. Accordingly, a generator's overall revenues equal the amount of payments in a FIT system when the weighted average of achieved market prices corresponds to the industry average. If individually achieved market prices exceed or fall short of the average in a certain period, the revenues diverge from the FIT level. This means that investors bear risk related to the correlation of their plants' availability for production with the availability of other OWE plants and with market prices. SMPs therefore generally also provide incentives to maximise market revenues (i.e., output quantities and production values). However, the significance of the incentives for investment decisions is even more questionable than in the case of FMPs. Apart from the general difficulty of forecasting market price patterns over the lifespan of power plants, the flexibility of the premium level reduces revenue implications. Occasional significant deviations from the FIT level tend to balance out over the long-term contract periods. Nevertheless, it cannot be entirely ruled out that future changes in plant construction trends lead to substantially different production patterns of other OWE generation. Therefore technical progress and investment decisions of competitors lead to certain revenue risks which potentially affect the costs of capital. Still, the sliding premium overall effect on risk premiums can be expected to be comparatively small. Against this background, there are also good reasons for establishing a cap to the possible market earnings of generators in an SMP scheme, if there is a reasonable likelihood that market prices could exceed the FIT level during the contract period.[9]

As mentioned above, in market premium schemes generators are usually responsible for selling electricity (whereas this is normally not the case in FIT regimes) and thus balancing. Whether direct marketing itself goes along with efficiency increases – as suggested by some contributions to the market design debate – has not yet been

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at the expense of increased investment costs. Under such circumstances, exposing investors to market risks potentially leads to improved decisions and more efficient outcomes.

[8] Similar problems occur when other remuneration schemes and RES-E instruments that expose investors to high market risks (such as renewable obligations) are applied.

[9] Otherwise consumer payments will increase in case of high market prices which is questionable in light of the great limitations to the downside risks borne by investors.

demonstrated. On the other hand, due to large sizes of OWE projects cost increases related to decentralised marketing (by each generator) can be expected to be moderate in comparison with other RES-E technologies. It could be further argued that balancing responsibilities (and market risk) incentivise OWE generators to provide flexible back-up capacity. However, it is not evident why this task should be assigned to exactly these actors at expense of OWE projects cost of capital. The need for flexible capacity is determined by the overall intermittent capacity in the electricity system. Urging individual generators to deliver capacity on their own might therefore result in inefficient small-scale solutions with economies of scale not being realised.

The assessment of remuneration schemes for OWE investments (which was presented here in condensed form) suggests that **FIT** and **sliding premiums**, in principle, offer a high potential regarding the limitation of costs. In contrast, concepts which expose OWE investment to high market risks appear to go along with considerable cost increases from both a welfare perspective and a consumer perspective.

2.2.2 Procurement mechanism

Considering the special characteristics of OWE projects, **tender mechanisms** appear to offer a generally suitable procurement framework. As explained in section 2.1, there are often good reasons for regulatory decisions regarding the locations of new OWFs. Setting the price as the key bidding parameter may be a promising approach to identify and select the most efficient generators and projects whilst limiting producer rents and thus consumer payments. The large size of individual OWE projects goes along with a comparatively low number of offers and thus relatively low transaction costs related to the participation in tenders. Nevertheless, a sufficient level of competition is a precondition for attaining desirable tender results. Since large projects usually attract investors of a certain size, the typical tender problem of creating entry barriers for small investors appears less important in comparison to other RES-E technologies.

In order to foster the development and application of major innovations, it could be reasonable that the selection of projects is not exclusively based on the offer price. Instead, the (future) value of technological evolutions should also be taken into account. Adequately weighing different criteria in a scoring mechanism for project selection might sometimes prove very difficult and thus lead to undesirable outcomes. Alternatively, the regulator can define separated procurement segments for innovative projects in which the offers do not compete against regular projects.

Although tendering new capacity does not necessarily involve deployment targets for many years ahead, it can be combined with regulatory commitments. Longer-term calculability is particularly important to OWE supply side actors, because large project sizes lead to step fixed costs at several stages of the supply chain. Therefore reliable trajectories for OWE expansion are essential for realising further cost reductions.

2.3 Summary and policy implications

The general considerations on the EOM and the CRM presented above by no means imply that in real-life electricity systems which apply an EOM-based approach a sudden transition to a comprehensive CRM scheme (for all generation technologies) would always be recommendable, since the particular circumstances of each situation play a crucial role. Instead, we come to the conclusion that it is reasonable to use targeted instruments for the provision of OWE capacity whenever an expansion of the installed capacity is intended; this explicitly also applies to situations in which OWE would be competitive in an EOM-based system as well.[10]

Regarding the design of the OWE instrument, especially in countries with ambitious expansion targets it could be reasonable that, in a first step, the regulator chooses the locations for new OWE installations and carries out basic development tasks. In this way synergies with grid connection planning can be realised and the amount of stranded investments related to abandoned generation projects can be limited. The site exploration is followed by a tender process which serves for selecting generators (and potentially their project proposals) as well as determining the corresponding levels of remuneration payments. With respect to the remuneration scheme, FIT or SMP regimes can generally both be regarded suitable for OWE projects, because the costs of capital are comparatively low.

In several EU member states the currently applied practices generally conform to these results. Meanwhile, other countries with serious interests in the development of OWE capacities should consider introducing similar targeted OWE regimes in order to create a reliable investment environment for generators who put the expansion plans into practice. However, concerning the implementation of theoretically sensible reforms of existing institutional frameworks, it is important to take their practical feasibility into account. In some cases it might not be possible to implement reform models without substantial modifications during the legislative process which drastically change the effects regarding the initially aspired goals. Besides, a certain degree of consistency and predictability in regulatory action is an elementary component of investment-friendly institutional frameworks. For this reason, care should be taken to avoid extensive devaluations of specific investments in the course of sudden paradigm shifts.

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[10] Against this background, the expression "support instruments" might be a suitable term for describing that the regulator promotes the development of RES-E technologies, if their costs and benefits are not appropriately reflected in the pricing mechanisms of the currently applied (EOM-based) market design. On the other hand, the term could be misleading, because the reasons for applying targeted instruments for the provision of RES-E plants (especially cost efficiency effects) do not disappear when a technology has reached a high level of competitiveness.

Sharing the costs and benefits: International cooperation on developing offshore wind generation capacity[11]

Two important factors for driving down OWE costs are technological progress and gained experience. Besides that, cost savings could also arise from international collaboration. One method of cooperation is the joint realisation of OWE projects. Although private actors usually play a very important role in developing OWE projects, for the following considerations we assume a greatly simplified setting in which public actors (hereinafter often referred to as "countries") develop OWE projects in order to reach certain national expansion targets. Assuming this setting, joint projects mean that two or more states engage in the common planning and implementation of OWE plants. Such an approach generally makes it possible to select OWE production sites exclusively based on cost aspects and regardless of national borders. This promises LCOE decreases and thus potentially overall welfare gains. Moreover, potential synergies arise in the context of planning (meshed) offshore grids and interconnectors; among other things, hybrid grid concepts which combine linking OWFs to the main grid with the extension of cross-border transmission capacities play a role in this context.

Despite the theoretical savings potential of joint projects, their implementation can be difficult. A main barrier is that joint projects often go along with complex cost and benefit effects which are usually not distributed equally among the participating countries (i.e., rent distribution might be unfavourable for some). In general, these problems could be tackled by adding further contractual arrangements regarding cost distribution. This, however, requires the determination of potential effects associated with the joint project. Since the effects they result from a large variety of complex interdependencies within the power systems, which continuously change over the course of a project's lifetime, this task might already go along with considerable transaction costs. The same applies to negotiations and the management of the cooperation contracts. Besides, contracts entered into by investors for the development of joint projects are always incomplete due to the large variety of possible scenarios and may therefore leave the contracting parties with considerable uncertainty.

A successful implementation of a joint project is most likely when achievable LCOE savings are high and transaction costs moderate, which is particularly likely, if there is a conducive transaction atmosphere between the countries; in other words,

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[11] The content of this text box sums up key aspects of the analysis in Albert Hoffrichter and Thorsten Beckers, "International Cooperation on the Expansion of Offshore Wind Generation Capacity – Potential Benefits and Pitfalls of Joint Projects from an Institutional Economic Perspective," Research Paper, 2018.

transaction costs should not offset the potential gains arising from cooperation. If countries are already involved in other cooperative projects, reaching an agreement tends to be easier and further synergies might arise.

Supranational institutions can play an important role in overcoming obstacles to the realisation of joint projects. They can provide platforms and frameworks for cooperation in order to reduce the costs of individual transactions since general standards can be applied. Moreover, they can directly involve themselves in OWE cooperation initiatives and assist in the determination of effects or help countries reach agreements. They can act as a neutral institution to resolve conflicts during contract periods and reduce costs related to the design, negotiation, and reinforcement of cooperation contracts. Additionally they can provide financial support out of centralised funds for welfare enhancing joint projects in order to increase the attractiveness for the involved parties or overcome possible financing gaps; besides, such funding might reduce the costs of capital. However, not all measures taken by supranational institutions which are intended to foster cooperation are likely to reduce costs. In particular, virtually forcing countries into agreements could lead to the realisation of joint projects that are unfavourable for some actors or even overall; final decisions should therefore be left to the countries.

The EU, in general, provides a comprehensive framework for international cooperation. Many existing European institutions with ruling competencies can, in principle, help to resolve conflicts that arise during the contracting period of joint projects. Several EU institutions also specifically offer support to collaboration initiatives which arise on a decentralised level; however, the programmes do not apply to "regular" power generation projects, including joint OWE projects. Regarding the financial support of projects in the electricity sector a variety of programmes with different selection procedures exist. Grid extensions are supported, for instance, when large positive effects on the interconnected power system emerge, whereas generation projects only receive direct payments from centralised funds when particularly innovative aspects are involved. The restraint in funding generation projects is reflecting the EU's internal market goals regarding power generation. Instruments available for OWE projects are loans and other financial instruments provided by the European Investment Bank, which also advises on administration and development questions. There are no binding requirements for EU countries to implement joint generation projects. Instead, Member States are pushed to open national RES-E support schemes to plants located abroad, which seems questionable for similar reasons; the same applies to the increased pressure on countries to modify their national support schemes in order to comply with centrally established standards that aim at enhancing competition within the EU.

Text box 1: International cooperation on developing offshore wind capacities.

3. Institutional framework for the development of (meshed) offshore wind grid infrastructures (DTU)

Meshed grids solutions combine both cross-border transmission and offshore windfarms connections.[12] They consist of integrated, dual-purpose and multi-actor projects, in the sense that they enable the exchange of electricity through interconnections and connect the OWF and can involve more than two actors (for instance several TSOs and OW operators). They open untapped possibilities for future decarbonised systems but also call for intensive adjustments in current regulatory frameworks.

3.1 Offshore meshed transmission grids: A new option for future European networks

An expansion of OWE capacity must be accompanied by an **expansion of grid capacities which explains why reaching a low carbon energy future is highly associated with large network investments**. In order to reach European decarbonisation targets, it is expected that future investments in transmission grids will reach EUR 125 to 140 billion until 2030, and up to 420 billion until 2050. However, according to energy experts, only half of this investment is expected to be made due to the **inadequacy of current regulatory frameworks.**[13]

It is the combination of ambitious RES-E development goals and the transmission network investment challenge that supports the emergence of hybrid architectures such as meshed grids.

Offshore meshed grids open an array of new opportunities to OW operators, TSOs and the rest of the society. They present extensive benefits in terms of economic and environmental efficiency as well as in terms of reliability as compared to traditional uncoupled connection and interconnection architectures. The integration of OWF to interconnectors generates synergies and cost savings in improving the utilisation factor of network capacities and increasing the value of the electricity produced. Offshore meshed grids also strengthen market coupling with positive effects in terms of price convergence

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[12] Section 3 contains a summary of Claire Bergaentzlé and Lise-Lotte Pade, "Regulatory barriers to offshore meshed grids: A TSO perspective illustrated with the Baltic Sea countries", Working Paper, 2018.

[13] Henriot, Arthur. 2013. "Financing Investment in the European Electricity Transmission Network: Consequences on Long-Term Sustainability of the TSOs Financial Structure." *Energy Policy* 62. Elsevier, pp. 821–29. doi:10.1016/j.enpol.2013.07.011, p. 882.

and competition. They give access to more diverse energy mix therefore reducing the need for additional reserve capacities and strengthening systems reliability. Offshore meshed grids are expected to lower curtailments and are consistent with national long-term capacity adequacy and interconnection plans. Future developments of offshore meshed grids should finally result in positive externalities in terms of CO_2 emission reductions, faster energy transition; offshore wind energy market uptake; minimisation of support schemes and increased regional welfare.

However, offshore meshed – and hybrid – grids development also face substantial regulatory challenges, mostly due to their capitalistic nature and of the involvement of multiple stakeholders.

Offshore meshed grids result in higher upfront investment costs as compared to classical infrastructure, mainly driven by the use of HVDC technology and the multiplication of transformers. Economies of scale building on large installed capacities and sufficient grid infrastructure are consequently determinant in meshed grid projects to reach long term economic profitability, which also stresses the need for coordination and joint effort between the involved partners at the regional scale.

While learning curves are expected on the technical-side to lower the investment constraints, important efforts are yet to be made to support short and long-term coordination in grid operation and investment. Currently, regulatory frameworks are unsuited to promote hybrid infrastructures. The multiplicity of stakeholders combined with different national regulatory interests makes meshed grid planning, development and operation challenging. The identification, and lifting-up, of key regulatory barriers then becomes critical prior engaging into future discussion into meshed grid development. More specifically, supportive regulatory framework conditions should create a level playing field in relation to cost allocation, risk sharing and financial incentives at the sea basin level.

3.2 Regulatory framework

The operational complexity, the need to reach a high degree of convergence in the planning and investment activities of meshed grids should shape the designs of suitable regulatory frameworks.

The diversity in **cost allocation approaches for OWF connection, of grid utilisation tariff s and in the regulatory regime associated with TSOs' investments** are considered key regulatory barriers to offshore meshed grids as developed hereinafter. [14] On the bright side, important efforts were made to harmonise practices in system operation that may bring about inspiring perspectives on how to promote coordination in multilateral infrastructure investment.

3.2.1 Connection cost allocation

TSOs are responsible for building the transmission grid infrastructure. The viability of OW projects is greatly influenced by the **allocation of grid connection costs** between the two stakeholders. The connection costs reflect the investment in new infrastructure assets to connect the OWF to the onshore grid and vary in function of the OWF capacity, distance to shore as well as the depth of the OWF location. OWF connection may also affect existing infrastructure and involve reinforcements of onshore assets.

Several cost allocation models prevail, where TSOs, OWF developers or in some cases, third parties such as in the UK, participate to the investment effort, involving various degrees of financial risk for each stakeholder associated to the grid funding. For instance, in a super-shallow approach, the TSO (and the rate payers) almost entirely internalises the financial risk associated with network construction which precisely supports OW development initiatives. In contrast, a deep approach adds on the financial risk borne by the OW developer and will ultimately reflect in the bidding strategy and competitiveness of the market actor. Models where OWF developers must bear part or all of the connection costs also send a locational signal that may potentially result in a trade-off between least-cost location in terms of network development and optimal location in terms of wind condition. The resource-dependency of wind energy makes the deep connection method relatively unsuited in view of the uptake of efficient offshore wind production.

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[14] Other regulatory barriers may be for example complicated administrative procedures for project planning or different legal “interpretation” of grid assets status such as the legal status of dual-purpose cables.

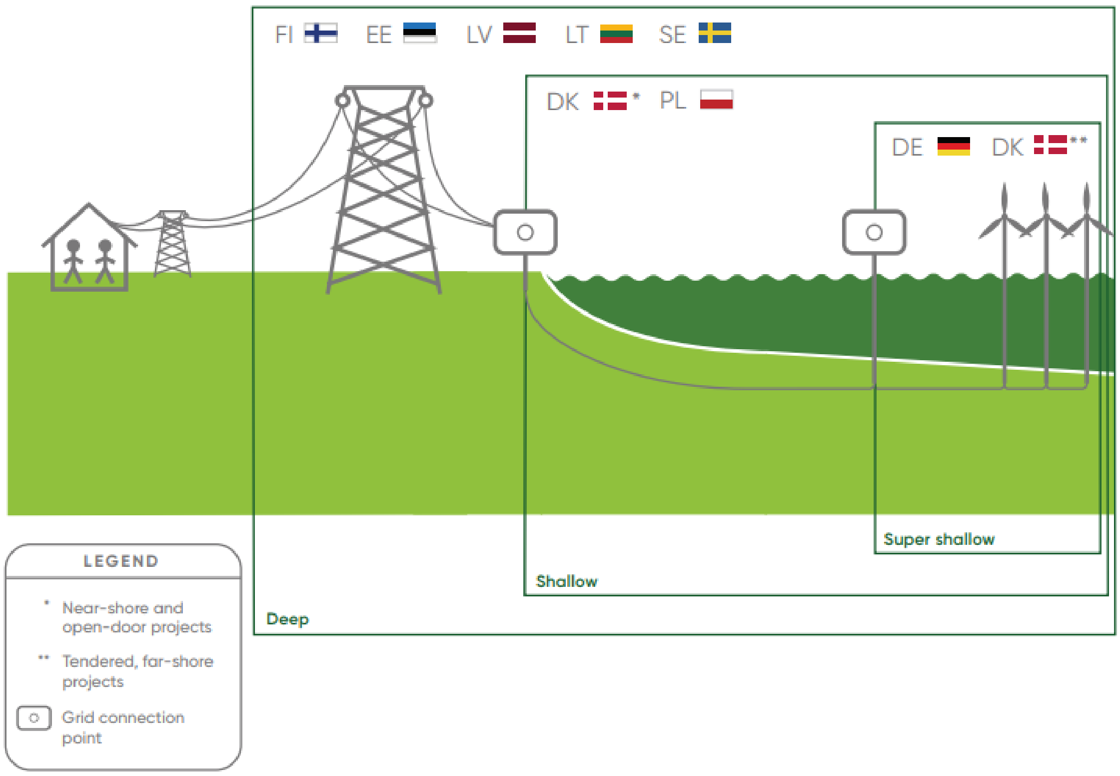

Figure 1: Cost allocation for grid construction.

In a meshed grid architecture involving several TSOs, connection cost allocation models are critical both in relation with the kind of signal that is sent (level of risky) and in the homogeneity of this signal within the area.

In view of the development of an optimised meshed grid for the development of offshore wind power, a **super-shallow approach** where only TSOs bear the costs associated with grid development is preferable. This approach *de facto* eliminates locational signals, thus limiting potential distortions in investment decision from the OW operator. Measures to outweigh the potential over cost impact due to the lack of locational signals should nevertheless be introduced to mitigate grid expenditures. The main question to address is **how to share cost among the involved TSOs**. The Economics viewpoint in relation to cost allocation advocates investment burden should be proportionate to the effective benefits expected from the infrastructure, potentially reducing the grid development burden for individual operators. In a multi-actors network, cost-reflectiveness criteria can however be uneasy to capture, making connection cost sharing blurry. In that respect, the cross-border cost allocation (CBCA) initiative from ACER and the ENTSO-E to apportion costs in projects of common interests consists of a possible line of approach in an offshore meshed grid context since it captures multilateral investments constraints and accounts for externalities.

3.2.2 Tariff design and utilisation of the network

The grid access charge, or tariff, reflects the cost to utilise the grid infrastructure and is paid by grid users (generators and end-consumers[15]). The superposition of different tariffs may be a barrier to joint projects as different fees may be charged by the involved TSOs, resulting in uneven incentives to connect to and to feed in the meshed grid.

Three main factors that directly relate to the tariff design have to be considered.The level of the tariff paid respectively by generators and consumers should be harmonised. Usually, the contribution of generators to network utilisation (the G-charge) is null, such as in the three Baltic countries, Germany and Poland, or limited, such as in Denmark. A handful of countries apportion the access charge in a way to even out to some extent the charges paid by both party (the G-charge in Finland and Sweden goes from 19 to 36%). Harmonisation should also be addressed in the structure of the access fee, that is, in the allocation in the access charge between energy and capacity component. In Denmark the access charge structure is entirely based on the energy charge, meaning that for each unit of energy generated, a network fee is paid. Sweden and Finland apply a capacity-based charge on top of the energy charge. While the energy component adds a fee for each unit of electricity fed in the network, the capacity charge is paid per period, regardless of the electricity produced, which discriminates generation units with a low load factors such as OWF. Some tariffs also include additional features such as a locational component. Similarly to the connection cost approaches, locational elements in the access charge would have the effect to discriminate resource-dependent generation units against traditional generation.

In a meshed infrastructure system, it is necessary that grid access tariffs are harmonised to limit uneven business opportunities and operation costs for OW developers, with detrimental impact in terms of competition and LCOE. A **common access charge should thus prevail to create a level playing field and prevent distortions at the offshore meshed grid level.**

A first step towards more harmonisation is brought by the ACER's initiative which sets that access charges should reflect the network operating costs and should be set between 0 and 0,5 EUR/MWh.[16] However, this measure is still incomplete as some countries such as for example Denmark, Sweden or Finland are exempted from these regulations and can

[15] According to EU rules, interconnectors are not subject to access charge; this is attributable to their status that is recognised neither as generation nor demand.

[16] Commission Regulation (EU) 838/2010 of 23 September 2010 on laying down guidelines relating to the inter-transmission system operator compensation mechanism and a common regulatory approach to transmission charging. Official Journal of the European Union.

apply access charges up to 1,2 EUR/MWh. In addition, no guidance is provided on capacity charges or other costs features such as locational signals, which leaves substantial room for improvement in future tariff adjustments.

3.3 Rate making: Zoom on the cost recovery of regulated expenses

The investment challenges that lay ahead for European energy strategy question to some extent the suitability of dominant regimes and call for more flexibility in the funding of innovative technical and organisational solutions. Investments in grid infrastructure are performed by TSOs in response to binding legal obligations (for instance to achieve interconnection targets or connect renewable generation units) and to a set of regulatory incentives. The instrument package designed by the regulator should be used as a tool to drive capital and operation expenses and to facilitate cooperation among TSOs. Based on the design and combination of the incentive instruments and the particular item of expenditure they apply to, the investment risk and degree of effort expected from the TSOs to perform according to predefined criteria may differ significantly.

A sound regulatory regime for rate making should strike a balance between risk minimisation in a very limited information environment associated with capital intensive innovative investment in a multiplayers context. An offshore meshed grid-friendly regulatory regime should be designed according to the characteristics of such investment that can be summarised as being: capitalistic; meaning that covering the investment risk should be prioritised while maintaining the overall expenditure low; Innovative; meaning that low information is known from both parties (the regulator and the TSO); Unlocks efficiency gains; meaning that the capture and measurability of such gains can be used as trigger for the investment; And encompasses national boundaries; meaning that coordination in investments and incentives should be reached at the regional level.

Current regulatory regimes are however inherited from periods characterised by over-capacity in infrastructure assets when the main objective for regulatory agencies was to incentivise cost cuttings. They are therefore limited to incentivise offshore meshed grid investment and generally speaking are outdated to instigate investment booms at a least cost. **The investment challenge that lays ahead meshed grids thereby questions the suitability of dominant regimes and calls for more flexibility in the funding of innovative solutions. Incentive instruments exist to address each of these features.** For example, the UK extended its regulatory period to allow grid operators to reduce the financial risk associated with the heavy investments expected to comply with British decarbonisation effort. Germany operates a clear distinction between controllable and non-controllable capital expenditures and applies different sets of incentives depending on the expected cost efficiency grid operators can reach. In California a new set of metrics was developed to couple profit with new performance objectives associated to smart grids development. Similar performance-based indicators could be constructed to associate offshore meshed grids benefits to the TSOs' profit.

However, what is missing is a coherent regime offering a combination of the best incentive instruments to trigger investments in offshore meshed grids, and the institutional framework that precedes the establishment of a coherent regime across borders.

3.4 Towards harmonised system operation

In addition to a greater convergence in the applicable rules for capital investment, a high level of coordination for the short-term operation of offshore meshed grids is needed. The lack of harmonisation in network operation activities limits cross-border electricity exchanges[17], including through offshore meshed grids, and more generally limits the integration of RES. A review of recent initiatives taken at the European level indicates that important efforts have been accomplished to improve short-time operation. This is the result of a progressive adoption of common operation rules and network codes that have paved the way for more interoperability and harmonised balancing mechanisms across transmission zones. Because the operation of offshore meshed grid is intrinsically linked to security of supply in a highly variable generation context, these initiatives are considered supportive regulatory frameworks.

The European Commission Regulation (EU) 2017/ 2195 sets a framework for cross-border balancing where TSOs are expected to cooperate closely to develop monitoring and calculation methods pursuant to the Electricity Regulation and are drafted to address cross-border network and market integration. The main argument for the network codes is to create an institutional framework that facilitates dialogue in trans-national projects. The joint calculation of available cross-border capacity is part of the thematic addressed in the codes and gives an illustrative example on how this framework supports integrated activities and can alleviate barriers to future meshed grids.

Today, capacity calculation is made by sub-regions. In the Baltic Sea basin, three different sub-regions co-exist (Nordics, Baltic and Hansa). Countries such as Sweden for instance belong to the three sub-regions. In a meshed infrastructure, it becomes necessary to define to which region the interconnectors belong to for capacity calculation. The network codes, without fixing a given rule, limit the possible alternatives. Because they are developed in the perspective of reaching future interconnection and RES-E development targets, the underlying foundation of the codes is expected to be consistent with meshed architectures.

On top of enhancing coordination in operation activities, significant efforts are also currently deployed to promote harmonisation in the market activities performed by the TSOs in relation to balancing services. Currently, a myriad of balancing market designs co-exist in Europe (For a review see the ENTSO-E survey[18]). The Network Code on Electricity

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[17] Friends of the Supergrid, 2010, Position paper on the EC Communication for a European Infrastructure Package, p. 15.

[18] Entso-e. 2017, "Survey on Ancillary Services Procurement, Balancingmarket Design 2016".

Balancing (NC EB)[19] has recently set the legislative guidelines for European TSOs to develop common principles for the harmonisation of balancing energy services.[20] Final authorised propositions should be enforced in 2019. The aim of this regulation is to develop cross-border European platforms based on a multilateral TSO-TSO model using common governance principles ensuring non-discrimination.

The guidelines are consistent with meshed grids as they address the variability from wind energy. In that sense, it increases the value of wind energy and the market profitability of meshed grid infrastructure. Besides, they promote harmonisation in future exchanges of ancillary services across borders, which is crucial in meshed architectures. However, a comparison between the guidelines and current balancing markets design tends to show that the effective implementation of the guidelines may be more burdensome in some countries than in others.[21]

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[19] Commission Regulation (EU) 2017/2195 of 23 November 2017 establishing a guideline on electricity balancing, OJ L 312, 28.11.2017, p. 6–53.

[20] Art. 19-21 NC EB.

[21] For instance, the Nordic countries may have to make more adjustments in the design of the automatic frequency restoration reserve while continental Europe may have more difficulties in complying with the settlement mechanism associated with manual frequency restoration reserve.

4. Conclusion

In light of drastic LCOE reductions in recent years and large reductions in the context of gained experience and technical progress yet to be realised, OWE has the potential to play a key role in future energy systems. Although especially new OW projects have already proven the technology's competitiveness, the costs of OWE are sometimes still perceived to be comparatively high. One of the main reasons leading to this perception is that national regulatory frameworks often do not provide an adequate environment for OW investment which results in substantial cost increases. Recognising the importance of the institutional framework and making adaptions if considered necessary is therefore essential for realising the technology's potential. Presenting the analyses of three comprehensive working papers, in this report we discussed the importance of the regulatory framework for the expansion of OWE capacities with respect to both generation investment and grid investment.

Regarding generation investment, a large number of aspects deliver strong arguments for applying technology-specific instruments rather than relying solely on market mechanisms. With great uncertainty about future developments and limited hedging possibilities, the cost of OW investment in EOM-based market environments would be unnecessarily high and it is questionable whether a large-scale OWE deployment would take place. A purpose-oriented distribution of decisional responsibilities and risks between generators and the regulator (i.e., the consumers) can be established in the context of targeted OW regimes which provide long-term contracts for generators who implement public decisions to increase OW capacities. The higher the regulator's knowledge on power markets and instrument design, the better the instrument design can be adapted to the prevailing conditions. In many cases it could be reasonable to centralise the selection (or at least preselection) of production sites and to put out contracts for building and operating OWFs in these locations to competitive tender. Remuneration payments for the selected generators could be based on the FIT approach or the SMP approach, which both allow for comparatively low costs of capital. The selection of suppliers and the determination of payment levels could be based on the offers received in the tender. Ideally, this leads to selecting the most efficient projects and generators, while avoiding excessive producer rents. However, aspects apart from the offer price should also be taken into account. With respect to long-term efficiency it is, for instance, very important that the regulator actively enables the development and application of innovative OWE concepts. Last but not least, due to high step fixed costs at several stages of the OW supply chain, regulatory commitments to reliable trajectories for the expansion of OW capacities represent another source of significant cost reductions.

Concerning the regulation of offshore grid investment, providing a framework which promotes the implementation of meshed or integrated grid architectures (instead of radial connections) is a key challenge. Meshed grid infrastructures span over various regulatory jurisdictions governed by different regimes and institutional architectures. The difficulty in developing an adequate regulatory framework lies in the hybrid nature of the infrastructure, which encompasses both dual-purpose and multilateral dimensions. With such an architecture, the general acceptation of a legal definition for the transmission asset is critical as it will directly affect the design for regulatory frameworks. For example, if a given asset is recognised as an interconnector, this definition automatically entails that the TSO (or an independent third-part actor) is responsible for all development aspects. If the same asset is legally considered part of the transmission network, investment burdens can be allocated between the national TSO and relevant stakeholders such as OW operators, in which case the respective responsibilities for developments between stakeholders will depend on the national jurisdiction the asset belongs to. Currently, transmission grid development occurs in regulatory set-ups developed to achieve national interests (rather than overall welfare benefits), thereby offering limited perspectives on offshore meshed grid development. Success in future offshore meshed grid development requires that adjustments are made to current frameworks. More specifically, offshore meshed grid projects call for enhanced cooperation at the regional scale, better project integration between OW connections and interconnectors, as well as harmonisation in investment efforts and system operation. Regulations should therefore promote regional harmonisation in order to create similar conditions for investments in and operation of grid assets. Continuous efforts are being made at the European level to create suitable institutional frameworks for the actors concerned that include common methodologies and rules to enhance system operation efficiencies. They represent important steps towards the coordinated operation of hybrid network infrastructures in the future. However, as far as network capital investments are concerned, similar initiatives and harmonisation efforts are still lacking.

The prevalence of national-based methodologies for OW connection cost sharing, calculating grid access tariffs and setting financial incentives in the regulatory regimes creates uneven risks for both TSOs and OW developers that are likely to result in distortions in the development choices made by the involved stakeholders. Regulation should therefore address the barriers that prevent the involved actors from facing similar investment risk.

Using a single set of approaches for infrastructure cost allocation at the meshed grid scale seems unavoidable to support unbiased development. A cost distribution method based on the “who benefits pays” approach is difficult to implement due to the hybrid nature of the infrastructure that blurs the direct relationship between investment and expected benefits. Assuming that promoting OW development is an underlying objective of cost allocation, a supportive framework should avoid locational signals sent to the OW developers (such as in a deep approach) and let the financial risks be borne by the TSOs and the society. Grid utilisation tariffs based on consistent, if not commonly shared, tariff structures should also avoid locational signals and respond to cost-reflectiveness principles, advocating that OW operators pay for their use-of-system cost in time. Finally – similar to the case of generation investments – reliable long-term RES connection and interconnection goals, backed by appropriate and consistent regulatory regimes and increased coordination across regulatory agencies, reduce the investment risk for capital intensive grid assets.